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## PATENT APPLICATION

## IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicant(s) : Simon FENNEY et al.  
Title : METHOD AND APPARATUS FOR COMPRESSED DATA STORAGE AND RETRIEVAL

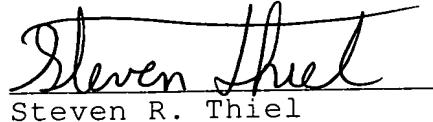
Serial No. : 10/621 111 Group: 2628  
Confirmation No.: 8439  
Filed : July 16, 2003 Examiner: Nguyen  
International Application No.: N/A  
International Filing Date : N/A  
Atty. Docket No.: R&G 361

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

## FIRST CLASS MAILING CERTIFICATE

Sir:

I hereby certify that this correspondence is being deposited with the United States Postal Service under 37 CFR 1.8 as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on November 2, 2006.



Steven R. Thiel

SRT/cc

FLYNN, THIEL, BOUTELL & TANIS, P.C. 2026 Rambling Road Kalamazoo, MI 49008-1631	Dale H. Thiel David G. Bouteil Terryence F. Chapman Mark L. Maki Liane L. Churney Brian R. Tumm Steven R. Thiel Donald J. Wallace Sidney B. Williams, Jr.	Reg. No. 24 323 Reg. No. 25 072 Reg. No. 32 549 Reg. No. 36 589 Reg. No. 40 694 Reg. No. 36 328 Reg. No. 53 685 Reg. No. 43 977 Reg. No. 24 949
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Correspondence: Priority Document Transmittal, and Claim of Priority dated November 2, 2006, with enclosures listed thereon

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## PRIORITY DOCUMENT TRANSMITTAL, AND CLAIM OF PRIORITY

Sir:

Applicants hereby claim the right of priority based on United Kingdom Serial No. 0216668.4, filed July 17, 2002.

Enclosed are:

- A certified copy of the priority application in support of the claim of priority.  
 Acknowledgment Postal Card.

Respectfully submitted,

Steven R. Thiel

SRT/cc

FLYNN, THIEL, BOUTELL & TANIS, P.C. 2026 Rambling Road Kalamazoo, MI 49008-1631 Phone: (269) 381-1156 Fax: (269) 381-5465	Dale H. Thiel David G. Boutell Terryence F. Chapman Mark L. Maki Liane L. Churney Brian R. Tumm Steven R. Thiel Donald J. Wallace Sidney B. Williams, Jr.	Reg. No. 24 323 Reg. No. 25 072 Reg. No. 32 549 Reg. No. 36 589 Reg. No. 40 694 Reg. No. 36 328 Reg. No. 53 685 Reg. No. 43 977 Reg. No. 24 949
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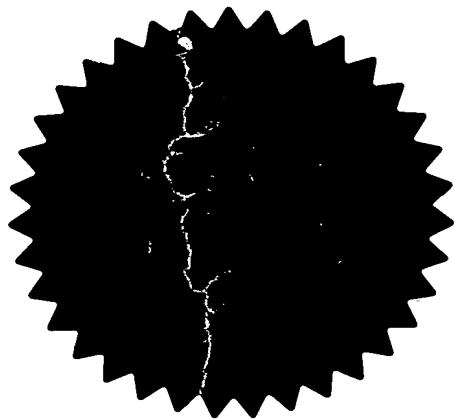
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Signed

Dated 20 September 2006

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THE PATENT OFFICE  
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The Patent  
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1/77

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17 JUL 2002 E734195-2 D01631

44886/AJR/JMV P01/7700 0.00-0216668.4

0216668.4

17 JUL 2002

Imagination Technologies limited  
Home Park Estate  
Kings Langley  
Hertfordshire  
WD4 8LZ

7142180  
Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of incorporation

England and Wales

4. Title of the invention

Method and apparatus for compressed data storage and retrieval

5. Full name, address and postcode in the United Kingdom to which all correspondence relating to this form and translation should be sent

Reddie & Grose  
16 Theobalds Road  
LONDON  
WC1X 8PL

91001

Patents ADP number (if you know it)

Country

Priority application  
(if you know it)

Date of filing  
(day/month/year)

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing  
(day/month/year)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:  
a) any applicant named in part 3 is not an inventor, or  
b) there is an inventor who is not named as an applicant, or  
c) any named applicant is a corporate body.  
See note (d))

YES

**Patents Form 1/77**

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Description	5
Claim(s)	1
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Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)

Request for preliminary examination and search (*Patents Form 9/77*)

Request for substantive examination (*Patents Form 10/77*)

Any other documents  
(please specify)

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11.

I/We request the grant of a patent on the basis of this application.

Signature

Date

17 July 2002

*Reddie + Groves*

- 
12. Name and daytime telephone number of person to contact in the United Kingdom

A J ROBSON  
020-7242 0901

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## Method and apparatus for Compressed data Storage and Retrieval

This invention relates to a method of, and apparatus for, compressing data and a method of, and apparatus for, decompressing data. The invention may be used in a computer graphics system, and in particular, in a computer graphics system in the field of 3D computer graphics and for applying detail to otherwise smooth surfaces through use of a 'bump mapping' algorithm, in particular one based on storing per-pixel surface normals in a texture.

Blinn introduced bump mapping in "Simulation of Wrinkled Surfaces" (SIGGRAPH 1978, pp286-292). The computed shading of surfaces, which is typically done using a function of the incoming directions of light rays and surface normal, i.e. the vector perpendicular to the surface, gives important clues as to the orientation and also roughness of that surface. Blinn's bump mapping gave otherwise mathematically smooth surfaces the appearance of roughness (or bumps) due to changes in the shading caused by altering the computed surface normal on a per-pixel basis. The method uses texture mapping to obtain a perturbation vector to modify a surface's interpolated-per-pixel normal.

Peercy et al ("Efficient Bump Mapping Hardware", SIGGRAPH 1997, pp 303-306, and US Patent 5,949,424) devised a more efficient method that instead directly stored 'perturbed' normal vectors in the texture. These normals were defined relative to a localized tangent coordinate system. Each light vector had to be expressed in coordinates relative to the local tangent space coordinate system.

Because both the size of textures and the memory bandwidth consumed during texturing is an important factor in computer graphics, Fenney (European Patent Application 98 939 751 8) describes means of reducing the storage costs of the surface normal, which requires three coordinate values (XYZ), to just two values thus saving storage space and texturing bandwidth. This method takes advantage of the fact that the surface normals are unit vectors defined in the local surface coordinate space. As shown in Figure 1a, the unit normals are primarily restricted to lie in a single hemisphere.

As an alternative to the local tangent space system, the surface normal direction can be defined in the object's local coordinate space. Although this has the disadvantage that it is difficult (or impossible) to reuse portions of the bump texture for different areas of objects, it has the distinct advantages that it is cheaper to compute the interpolated lighting vectors and that there is no need to store per-vertex local tangent coordinate systems in the model. As an example, Warnes' technique (Patent WO9527268) starts with this basis and then uses vector quantisation to make it fast.

With the local coordinate space method, one can note that the surface normal directions are now arbitrarily distributed in all directions along the surface of a sphere of unit radius (see figure 1b), unlike the local tangent space system where they are generally spread over one hemisphere. Although the method of surface normal compression described by Fenney can be trivially extended by using an additional bit

to choose between the hemispheres, this is not ideal, as many of the possible data encoding patterns are wasted.

Although not intended for storage in bump map textures, Deering ("Geometry Compression". SIGGRAPH 1995, pp 13-20) presents a means of compressing a 3D unit vector into 18 bits by identifying six regions in every octant of the unit-radius sphere. Unfortunately, 18 bits is an inconvenient size for texture storage in a computer texturing device where the natural preferred size is typically 8 or 16 bits. Although it may be possible to reduce some of the precision of this method so that it does fit into, say, 16 bits, the method requires numerous tests as well as fairly expensive trigonometric functions. Because a contemporary 3D texturing system needs to be able to compute in the order of a billion texturing operations per second, it is important that these decompression operations are relatively cheap.

The invention in its various aspects provides methods and apparatus as set out in the claims to which reference should now be made.

Preferred embodiments of the invention provide a means of storing 3D unit vectors in a form that is both optimised for storage in a texture, and for ease of decompression in the texturing and shading engine of a computer 3D graphics system. They are capable of supporting both the local tangent space and the local coordinate space methods of representing surface normals. Finally, the preferred methods make more efficient use of the representative bits than that presented in European Patent Application 98 939 751 8.

Embodiments of the invention will now be described, by way of example, with reference to the attached figures in which:

**Figure 1a** illustrates the range of unit normals needed for the tangent space bump mapping method;

**Figure 1b** shows the larger range required for the local coordinate space method;

**Figure 2** shows the preferred assignment of bits to a 16 bit encoding of a unit vector in the invention;

**Figure 3** illustrates decompression method and apparatus embodying the invention;

**Figure 4** illustrates details of method and apparatus for the step in figure 3 of computing the inverse of the vector length;

**Figure 5** illustrates the distribution of possible normal locations which can be represented in an embodiment of the present invention using two 3-bit values;

**Figure 6** illustrates the distribution of possible normal locations for a known method of data compression and retrieval using an approximately equal number of storage bits to that used for the embodiment of the invention whose distribution is illustrated in figure 5; and

**Figure 7** illustrates the distribution of figure 5 for just one octant pair of the sphere together with the corresponding grid of 3-bit values

The invention has two main aspects. A means of representing 3D vectors, chosen from a set of points on the unit radius sphere, in a compressed binary encoding suitable for storage in computer memory, and means of converting said compressed format back into 3D unit vectors. As the clearest way of describing the invention is to illustrate the decompression process, this will be the approach taken.

In the preferred embodiment, each 3D unit vector will be encoded as a 16-bit value, as shown in figure 2. Each value consists of 3 fields: A 2-bit 'octant pair' identifier, 10, a 7-bit U parameter, 11, and a 7-bit V parameter, 12. It must be stated that other choices of numbers of bits for the U and V parameters can be made without altering the concepts of the invention.

Figure 3 gives an overview of the decompression apparatus. The 'octant pair', 10, is supplied to a decode unit, 20, that interprets the input values to produce a pair of numerical sign bits. (Note that this is shown merely for clarity -the encoding can be chosen such that the behaviour of this unit is trivial). The 'Add and Test Magnitude' unit, 21, adds the U and V values, 11 and 12, and compares the sum with 127 (half the maximum possible value of the sum of 7-bit U and V values). It outputs a flag based on the result. (In binary hardware arithmetic, this is a trivial operation).

Unit 22 takes the pair of sign flags from 20 and the magnitude comparison result from 21, and combines them with the U and V values, 11 and 12, to produce the vector, {X' Y' Z'}. This vector is in the direction of the unit vector but is not of unit length. Unit 23 computes the inverse of the length of the {X' Y' Z' }, and passes this to the scaling unit, 24. This then scales the vector to produce a unit vector result. The internal operation of these various units will now be described using a C-like pseudo-code notation.

Unit 20, produces two sign flags, *U**sign* and *V**sign*, based on the 'octant pair' identifier, 10, *OPI*. It should be appreciated that this is actually a completely trivial operation in hardware.

```
#define IS_POS (0)
#define IS_NEG (1)

switch(OPI)
{
    case "00":
        Usign = IS_POS;
        Vsign = IS_POS;
        break;

    case "10":
        Usign = IS_NEG;
        Vsign = IS_POS;
        break;

    case "11":
        Usign = IS_NEG;
        Vsign = IS_NEG;
        break;

    case "01":
        Usign = IS_POS;
        Vsign = IS_NEG;
        break;
}
```

```

        break;
    };

```

Unit 21, produces a single bit flag, WO, to identify to which octant of a pair of octants the data belongs. This can be described as:

```

If(u+v < 128)
{
    WO = 0;
}
else
{
    WO = 1;
}

```

Those skilled in the art will appreciate that, given the range of the input parameters, in hardware the comparison and assignments simple amount to OR'ing together the two top bits of the sum of the u and v values.

Unit 22 produces the initial, non-unit-length vector as follows.

```

If(WO==0)
{
    if(Usign == IS_POS)
        X1 = U;
    Else
        X1 = -U;

    if(Vsign == IS_POS)
        Y1 = U;
    Else
        Y1 = -U;

    Z1 = 127 - X - Y;
}
else
{
    Xtemp = 127 - V;

    if(Usign == IS_POS)
        X1 = XTemp;
    Else
        X1 = -XTemp;

    Ytemp = 127 - U;

    if(Vsign == IS_POS)
        Y1 = YTemp;
    Else
        Y1 = -YTemp;

    Z1 = -(127 - X - Y);
}

```

Unit 23 computes the inverse of the length of the initial vector as a fixed-point fractional binary number. It initially computes the square of the length of the vector by summing the squares of the components, i.e.

$$\text{LengthSQ} = X1 \times X1 + Y1 \times Y1 + Z1 \times Z1;$$

It will be appreciated that, due to the range of input bits and the calculations performed, the possible range of squared lengths is limited. In the preferred embodiment, this range is 5377 to 80645 inclusive.

The inverse square root of this squared length is then computed in a pseudo-floating point format, using a method known in the art. With reference to figure 4, this calculation can be done using a normalizing shifter, 50, to shift the input an even number of bits so that the most significant bit is in either one of the two most significant locations. The most significant 10 bits of the result, 51, effectively represent a fixed point number in the range [1,4), and are then used to access a lookup table, 52. This lookup table returns a fixed point result in the range (0.5,1] corresponding to the inverse square root of the input. This result combined with the shift amount divided by two, 53, then constitutes the inverse square root of the original squared sum.

Finally, Unit 24 just multiplies the pseudo floating point inverse (i.e. corresponding to a multiply followed by shifts and truncates) by each of the X', Y', and Z' components to obtain the normalized result.

The opposite of the decompression process, i.e. the compression, is essentially the described process run in reverse. A unit vector, V, is analysed and the signs of the X, Y, and Z components determine which octant the unit vector lies in. The vector is then scaled, to produce V1, so that the  $V1[Z] = 127 - |V1[X]| - |V1[Y]|$ . The U and V components can then be computed from the identified octant.

For illustrative purposes, figure 5 displays the distribution of normal locations for an example embodiment where U and V are only assigned 3 bits each. As a comparison, figure 6 shows the distribution of points for the adapted version of the method described previously by Fenney, using an approximately equivalent number of storage bits. As can be seen, the storage is not as even, nor as dense.

Figure 7 shows the distribution for just one octant pair of the sphere with the corresponding grid of U and V values.

It should be noted that this technique is also useful to other applications which require reduced cost storage of unit vectors. The compression of vertex geometry, as described by Deering, is one such application.

Claims:

- 1) A method of retrieving a 3D unit vector from compressed data, the data consisting of three fields, the method comprising the steps of:
  - a) identifying one of four octant-pairs from the data stored in the first field;
  - b) extracting a first and second values from the remaining two fields respectively;
  - c) comparing sum of said first and second fields, and if said sum is less than  $\frac{1}{2}$  of the maximum possible value, selecting the first octant of the octant pair, otherwise selecting the second octant of the pair;
  - d) computing initial X, Y, and Z coordinates based on the choice of octant;
  - e) normalising said X, Y, and Z values to form a unit vector.
- 2) A method of performing bump mapping in which localized surface normals are stored and retrieved using the method of claim 1.
- 3) An apparatus performing the steps of claim 1.
- 4) A texturing apparatus performing the steps of claim 2.
- 5) Data compression and/or decompression apparatus as hereinbefore described with particular reference to figures 2 to 5, and 7.
- 6) A method of data compression and/or decompression as hereinbefore described with particular reference to figures 2 to 5, and 7.

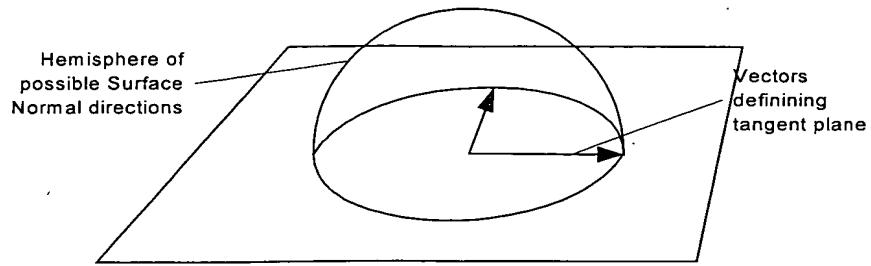


Figure 1a

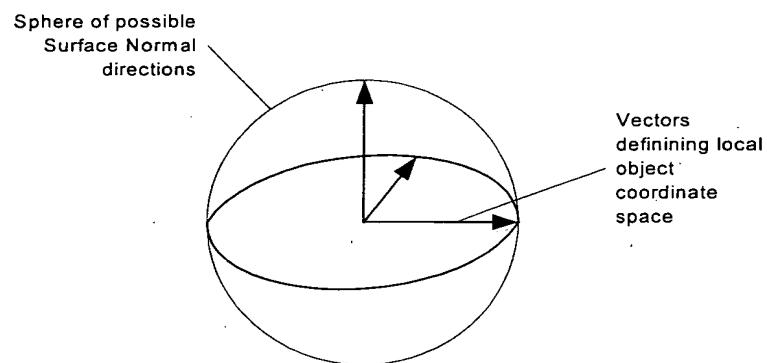


Figure 1b

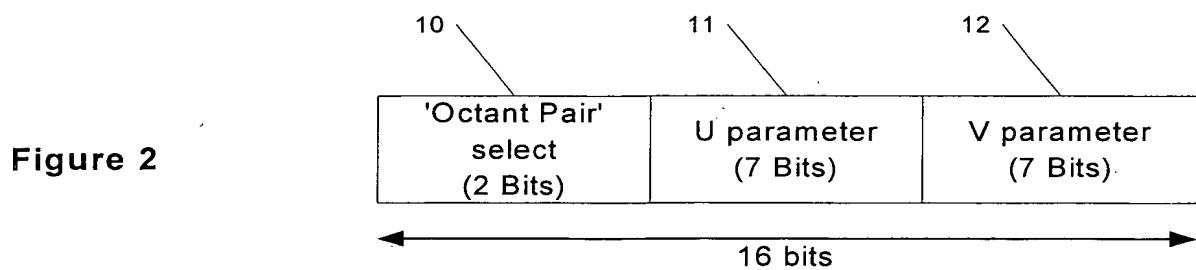


Figure 2

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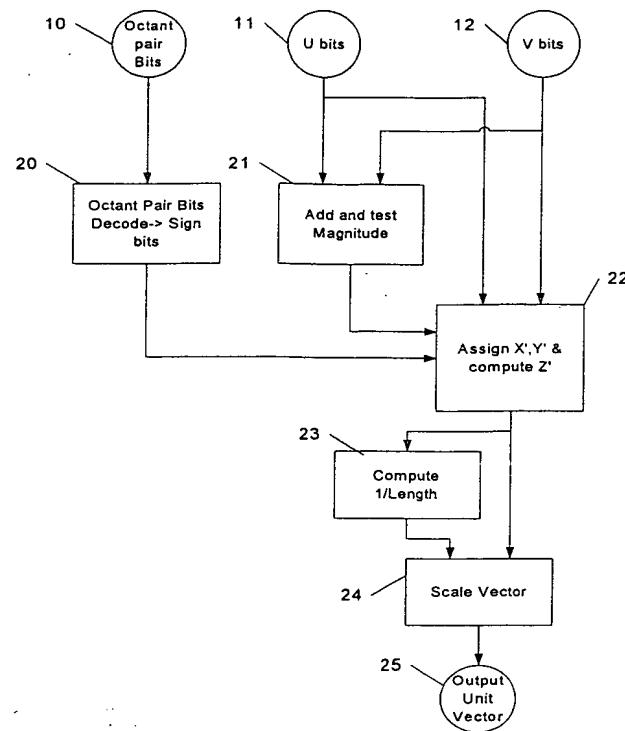
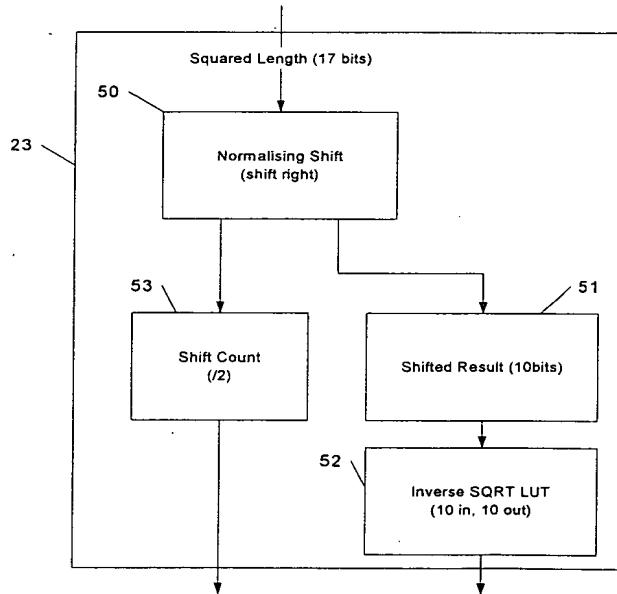


Figure 3

Figure 4



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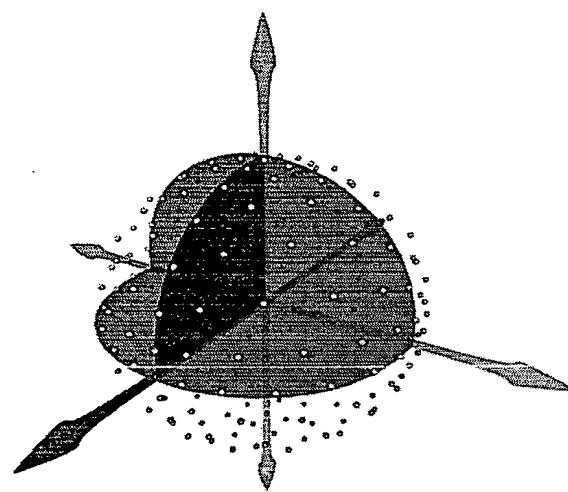


Figure 5

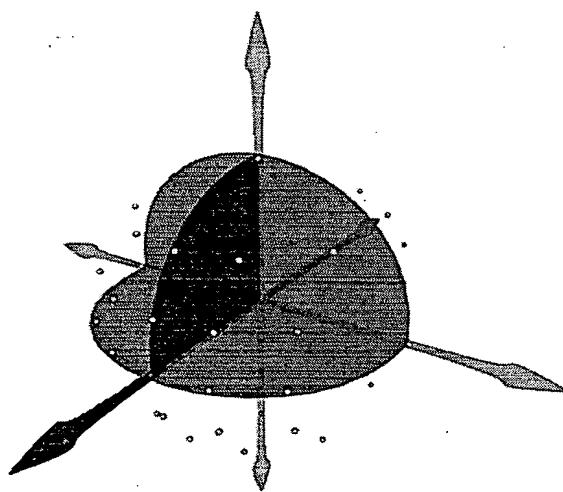


Figure 6

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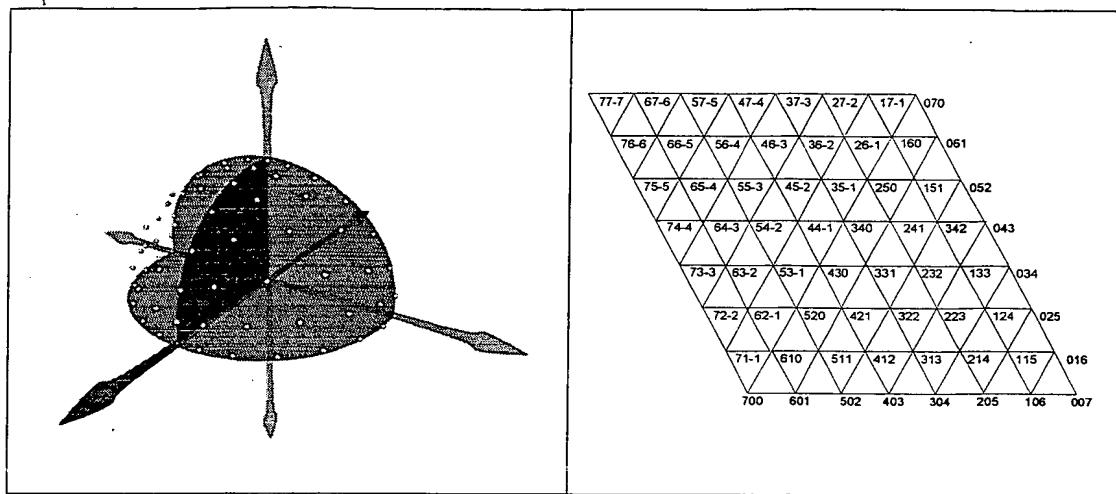


Figure 7

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